The Channeling (Microventing) Phenomenon in Young Marine Sediments

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LONG-TERM GOALS

To understand, evaluate, and quantify physical processes involved in the erosion, deposition, and transport of sediments. This involves short-term and long-term effects, and characterization of those effects based on sediment source and fluid mechanics. The outcome of this work will be a deeper understanding of the processes involved, and further development of predictive capabilities.

OBJECTIVES

The objective of the present research is to explore the causes of microventing, a phenomenon generally occurring in cohesive sediments during their deposition and consolidation. Microvents are characterized by volcano-like formations, remnants of the expulsion of fluid and sediment along a vertical channel through the sediment layer. The size of these vent formations ranges from the order of millimeters to several centimeters, hence the term "microvent." Several causes proposed for microvents may be generally grouped as biological processes and mechanical processes. An example of a biological process is the production of subsurface gas due to organic decomposition; rising bubbles can produce microvents. The present study is concerned only with mechanical processes, which are hypothesized to be: A) Pressure fluctuations in pore fluid; B) Solids concentration perturbations near sediment—suspension interface; C) Gas expulsion by sediment compression. The overall scope of this investigation is to describe the microventing process in pure clay sediments and in young marine sediment deposits. Specific tasks of this project are:

I) Identify whether microventing occurs in consolidation of kaolinite from a low initial concentration
II) Identify the control parameter for microventing through different methods of detection
III) Perform controlled tests to determine threshold of fluidization

Incorporate this knowledge into a numerical code

This information will ultimately be used in a quantitative model that predicts the rate of deposition and consolidation of sediment, but does not presently account for microvents (Papanicolaou and Diplas, 1999). Knowledge of microvent formation is also important in defining the erosional stability of young sediments, and such information will be useful to scientists and engineers in several disciplines, including those focusing on the prediction of fate and transport of contaminated sediments and those focusing on the refinement of existing remediation techniques in riverine and estuarine systems (Papanicolaou and Maxwell, 2002).

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APPROACH

In order to examine the hypotheses of this study, sedimentation tests have been performed in the laboratory using kaolin clay in water. A series of controlled experiments will be conducted to force microventing by means of water injection into the sedimentation column, in order to approximate the natural microventing. These experiments will be compared with forced microventing by air injection under identical initial conditions. It is believed that analysis of pore water pressure and total (solid and water) pressure time series will lead to better understanding of the causes of microventing, and allow discrimination between those causes. Spatial pressure gradients will also be examined in these tests, and image analysis will be used to compare the visible characteristics of the microvents, which are formed. Solids concentration gradients will also be examined non-destructively with a gamma radiation system constructed for this purpose. Adam Maxwell, a PhD student and Research Assistant, developed the experimental setup and will be performing the majority of future testing. Zhiqiong Hou, MSc student and Research Assistant, performed many sedimentation tests to satisfy Objective I, and is working towards Objective IV with the numerical code of Papanicolaou and Diplas (1999).

WORK COMPLETED

The experimental setup is completed and verified to work correctly. Objective I has been satisfied, and a natural microventing has been observed at sediment concentrations similar to that of a lutocline in an estuarine environment. Progress has been made on Objective IV, in that experimental results of Objective I have been shown to compare well with numerical results.

RESULTS

Previous research had ignored or discounted the possibility of microvents at such low concentrations as those examined under Objective I. Even for cases in which microventing has been observed, few detailed measurements for those cases exist. After further examination of literature and preliminary experimental results, it is believed that pressure is the governing parameter for microventing, and that changes in pressure may be caused by various means. Solids concentration gradients and expulsion of gas from consolidating sediments are two possibilities; these are expected to have different behaviors, just as fluidization by gas produces a different temporal and spatial response in a fluidized bed than fluidization by liquid (Duru and Guazzelli, 2002; Sundaresan, 2003). Although the effects of wave action on poro-elastic beds has been studied previously (e.g. Yamamoto et al., 1978), the present situation involves fragile flocs which may be more properly modeled by an elasto-plastic theory such as that of Buscall and White (1987). The present constitutive modeling practices (e.g. Tiller and Khatib, 1984; Bürger et al., 2000) can approximate the behavior of a microventing system in an average sense, but do not account for the mechanics of the process. More work needs to be done in this area.

IMPACT/APPLICATIONS

The present study has far-reaching impact in many disciplines. The focus in ocean and coastal engineering is on enabling more accurate predictive models of erosional strength and sedimentation, but ocean waste disposal practices are also affected (Pamukcu et al., 1990). There are also implications for many separation processes in chemical and environmental engineering; enhancement of mine waste separation and disposal is one example, as is remobilization of hazardous wastes

(Yanful and Catalan, 2002). Separation and centrifugation processes in biological sciences can benefit from this research, as well.

RELATED PROJECTS

Modeling of hyperpycnal flows and bed stability projects

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